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THE CHANNELED SCABLAND

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THE CHANNELED SCABLAND

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CONTENTS

	Page
General description	1
Annotated guide for the scabland and Grand Coulee	4
Great cataract group at head of lower Grand Coulee	6
Lower Grand Coulee	7
Coulee monocline and cliff summit west of Lake Lenore	9
Quincy Basin near Ephrata	9
Scabland and bars (?) of Crab Creek	10
Scabland and distributary canyons east of lower Grand Coulee	11
Hartline Basin scabland and gravel	11
Scabland and bars of High Hill anticline	12
Upper Grand Coulee	13
Route to Spokane over Sunset Highway	15
Bibliography	16

ILLUSTRATIONS

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		Page
Plate 1.	Diagrammatic representation of the channeled scabland of the Columbia Plateau and of the glacial Lakes Coeur d'Alene and Missoula in the Rocky Mountains	4
2.	Geologic map of Grand Coulee, Washington	4
3.	Dry Falls portion of the great cataract group, lower Grand Coulee	12
4.	Key to Plate 3	12
5.	Synclinal and monoclinal channels, lower Grand Coulee	12
6.	Key to Plate 5	12
7.	Lateral cataract recess and bar, upper Grand Coulee	12
8.	Key to Plate 7	12
9.	Heads of Northrup Canyon group, upper Grand Coulee, looking northeast	12

THE CHANNELED SCABLAND

By J Harlen Bretz

GENERAL DESCRIPTION

The originally plane surface of the Columbia Plateau in eastern Washington has been warped into a rudely semicircular basin, the lowest part of which is to the south, near the center of the arc that limits it on the east, north, and west. Centripetal drainageways roughly outline the radii, the Walla Walla, Snake, Columbia, and Yakima all joining within 15 miles (24 kilometers) or less of Pasco (altitude 381 feet, or 116 meters). Here the surface of the plateau basalt is below sea level, buried under fluviatile silt (Ringold formation) and river gravel. The southern rim of the semicircular basin is a sharply flexed asymmetrical anticline, in which the basalt rises 2,000 feet (610 meters) and more. All drainage escapes southward through this rim by way of the water gap known as Wallula Gateway. In all other directions the basalt surface rises much more gradually (except for local folds) and to greater altitudes. The abrupt contact with ranges of the Rocky Mountain system on the east and north averages 2,500 to 3,000 feet (762 to 914 meters) above sea level; on the west the basalt is folded up in the younger Cascade Range to 6,000 feet (1,828 meters). Some of these folds extend eastward 100 miles (161 kilometers) or more out into the plateau.

The plateau is separated from the mountains on the north by canyons of the westward-flowing Spokane and Columbia Rivers. In the northwestern part the Columbia leaves this peripheral course, enters the structural basin, and flows centripetally to the Pasco lowland. Consequent drainage determined by little eroded warps and folds of the basalt is a dominant feature of the region. There is almost no adjustment to structure by erosion: the drainage is essentially consequent, the anticlines are the divides, the synclines are the valleys.

This northern part of the Columbia Plateau contains a ramifying system of Pleistocene watercourses (the channeled scabland) unlike anything elsewhere in the world. The thick loessial cover has been stripped off the basalt along a multitude of linear tracts that descend the dip slope from the northern glaciated edge of the plateau. Preglacial valleys determined

the location of these linear tracts in large part, though some remarkable divide crossings exist. The escaping glacial water eroded the basalt beneath the loess, producing a complex of anastomosing channels, rock basins, buttes, cascade and cataract ledges, and residual islands of loess.

The glacial waterways are river channels, largely made over from preexisting river valleys. (See pl. 1.) Evidence for a system of capacious preglacial river valleys is widespread and unescapable. Extending far up on the slopes of these valleys are strongly expressed channel features. In many places the glacial water crossed divides of the earlier drainage pattern, cutting canyon channels where no valleys had existed. Large portions of the scabland channel system, if not all of it, were certainly contemporaneous in origin. These relations demand a volume of glacial water surpassing anything ever previously asked for in geologic interpretation. The time element in the flood hypothesis clearly can not extend through more than the briefest part of the erosion cycle now in progress and is apparently to be reckoned as a very brief part of one Pleistocene stage. The recency of the flood is attested by the freshness of the land forms it left—as fresh high on the channel valley slopes as in their bottoms.

The mature topography of the loess where unaffected by glacial streams breaks off sharply along the scabland channels in most places. The steep slopes of these channels descend to the scabland, truncating the older minor valleys and ridges. Hundreds of isolated loess hills and hill groups, surrounded by scabland, record the once complete loess cover. An area of 2,800 square miles (7,252 square kilometers) lost this cover and became scabland. The amazing display of rock basins is evidence of tremendous plucking in the closely jointed basalt. The great widths of some scabland tracts where no capacious preglacial valleys existed record streams as much as 20 miles (32 kilometers) across, which eroded rock basins and channels all over these wide floors. Some groups of closely associated channels, uniting and dividing in an intricate plexus, are truly canyons in depth. Their relations indicate simultaneous development and debar the idea that they might have been successively eroded. Some canyoned channels across preglacial divides are 100 to 900 feet (30 to 274 meters) deep. Cataracts from 1 mile to 3½ miles (1.6 to 5.6 kilometers) wide exist, and their recession during the flood stage amounted to as much as 10 miles (16 kilometers).

Deposits in the glacial streamways are almost wholly mounded gravel piles occurring in protected places in the channels or where decreased gradient or increased width locally caused

slacker water. They are little modified by subsequent run-off, and many of them originally blocked that run-off or are still blocking it. The structure of these mounds is especially interesting. Current bedding of the deltaic, foreset type is very common but bears such relations to the form that the mounds can only be interpreted as accumulations in place. Many of these mounds are hills 100 feet (30 meters) high and the tops of some are as much as 400 feet (122 meters) above their bases.

Records of a catastrophic flood in this part of the Columbia Plateau are not limited to the scabland complex. Such valleys of the centripetal drainage as contributed no glacial water to the scabland exhibit a curious record of flooding back into them from the scabland. Bar-mounded gravel lies in the mouths and back up these valleys, comparable in proportions, structure, and composition to the scabland bars but with their foreset beds dipping up the tributaries, away from the scabland. A widespread mantle of poorly sorted or wholly unsorted and unstratified pebbly silt overlies the loess on these valley slopes. It consists chiefly of rearranged loess with an abundance of sharp grains of basalt, some perfectly fresh, some weathered, associated with grains, pebbles, and even boulders of rock foreign to these valleys but widely distributed in the scabland débris itself. Even patches and lenses of till, with abundant scratched and striated rock fragments, occur in the pebbly silt. The upper limit of this mantle of débris, both vertically and horizontally, agrees with the requirements of the hypothesis. In each valley it attains but does not exceed the upper limit reached by scabland waters at the valley's entrance into the denuded complex. It is as prominent, as uneroded, and as unweathered on upper slopes as on lower. Its recency being as marked as that of scabland forms themselves, it can not be ascribed to earlier stages of valley development.

Grand Coulee (pl. 2), though an outstanding scenic feature, is but a small part of the scabland complex. It possesses almost every characteristic feature of scabland, and most of them are on the huge scale consistent with the flood conception. Grand Coulee is a tandem canyon across the northern high edge of the plateau, 50 miles (80 kilometers) long and 1,000 feet (305 meters) in maximum depth. The interruption between the two parts of the canyon, about 5 miles (8 kilometers) long, is due to a structural basin in the path of the glacial river. The upper coulee walls rise nearly 1,000 feet (305 meters) above the floor of the uncanyoned mid-length portion, and the lower coulee is eroded about 500 feet (152 meters) below this portion. The upper coulee extends completely across the divide

(the high edge of the plateau) and heads as a notch in the southern wall of the Columbia Valley about two-thirds as deep as that valley. This upper coulee is interpreted as a gorge left by a receding cataract. The cataract, by retreating completely through the divide and incising the southern wall of the Columbia Valley, destroyed itself. The conditions giving origin to the waterfall were (1) the absence of any preglacial valley along the site of the upper coulee, (2) the existence of a steep structural-topographic slope at what is now the south end of the upper coulee, (3) an ice blockade in the Columbia Valley a little west of the coulee, (4) the great volume of the glacial river, and (5) the capacity of the jointed basalt to maintain a recessional cataract.

The cataract as reconstructed far exceeds anything on the earth to-day. It plunged 800 or 900 feet (244 to 274 meters) to the water level in the cataract pool, it was 5 miles (8 kilometers) wide at its maximum, its plunge pool is of unknown depth, exceeding the deepest drilling of 200 feet (61 meters), and its recessional gorge is 25 miles (40 kilometers) long. For most of its life it was from 1¼ to 1½ miles (2 to 2.4 kilometers) wide, but during its retreat of 10 miles (16 kilometers) its width was three or four times as great.

Only a very small part of the scabland complex will be seen in the course of the excursion covered by the itinerary. Opinions based on observation will necessarily be limited to (1) the correctness in identification of scabland forms, such as cataracts, channels, plucked basins, and bars; (2) the possibility of their production by less water and more time; (3) the relative amounts of preglacial and of glacial stream erosion; (4) the part played by structural relief; and (5) the more remote possibility that the scabland ensemble is the work of glacial ice or some erosive agent other than glacial water.

ANNOTATED GUIDE FOR THE SCABLAND AND GRAND COULEE

Though there are scabland features along the Columbia Valley below Pasco, they are high on the valley walls and are difficult to recognize from the train. They will not be referred to in this guide.

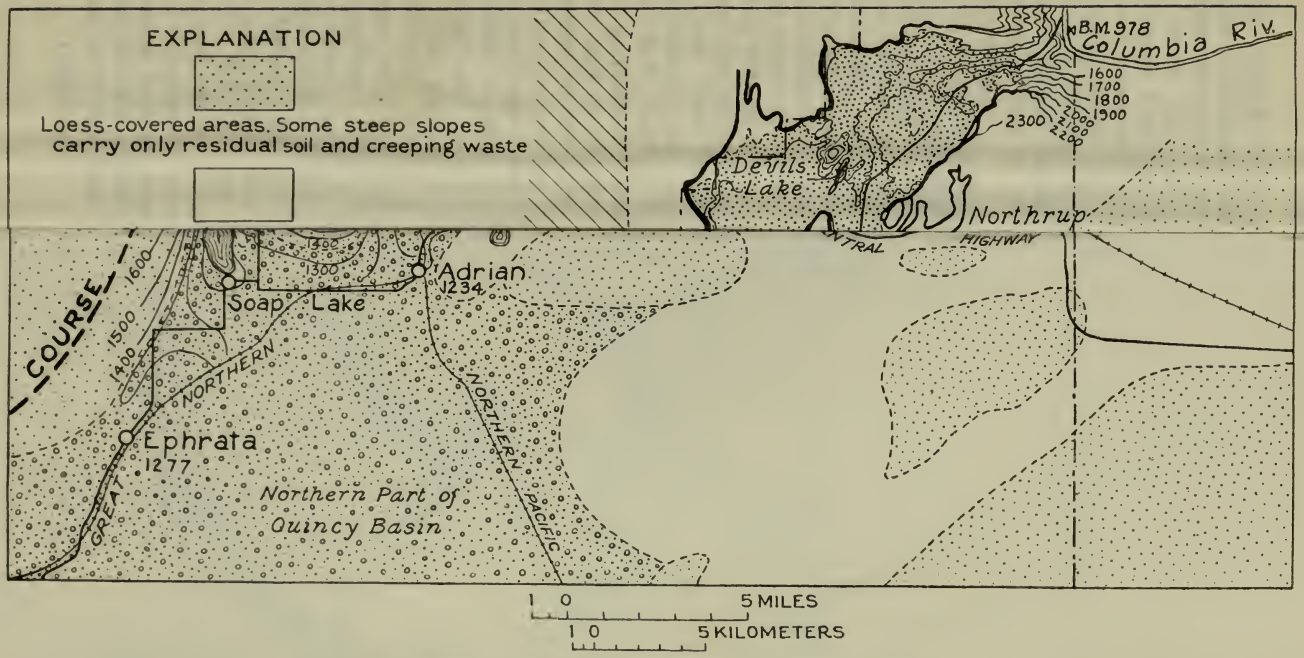
The first marked scabland features of the plateau encountered along the route lie north of Pasco. Their diagnostic features are not convincingly clear from the car window, but something of their general character is apparent. Between Eltopia and Connell there are high mounded gravel accumulations associated

DIAGRAMMATI D OF THE GLACIAL LAKES COEUR

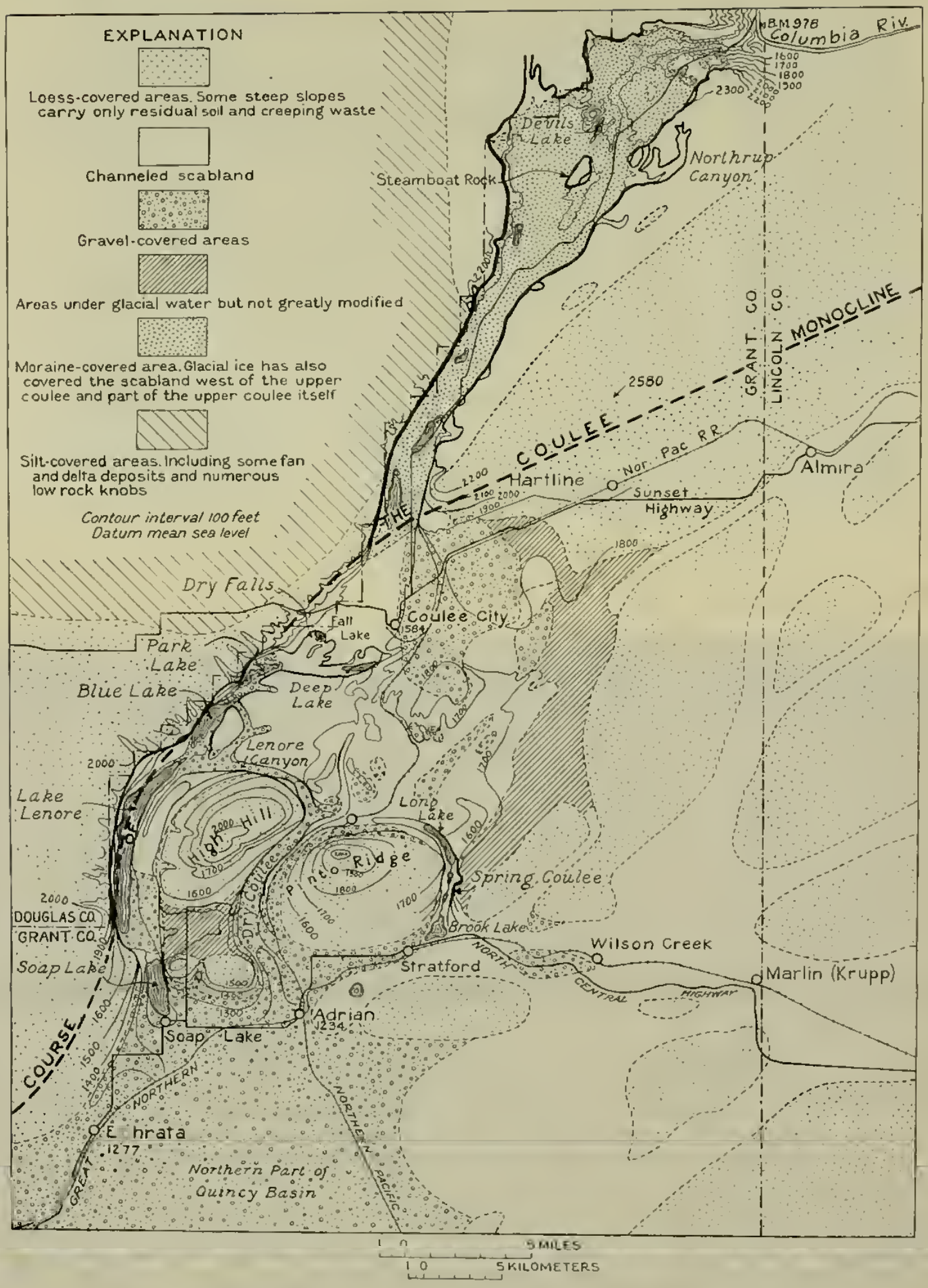
The highest records o s); channel heads along the northern edge of the plateau range fron am for glacial Lake Missoula at Lake Pend Oreille would allow about If an ice dam then existed in the Columbia west of Grand Coulee, thi United States," 1922.)

DIAGRAMMATIC REPRESENTATION OF THE CHANNELED SCABLAND OF THE COLUMBIA PLATEAU AND OF THE GLACIAL LAKES COEUR D'ALENE AND MISSOULA IN THE ROCKY MOUNTAINS

The highest records of glacial Lake Missoula are 4,200 feet (1,280 meters) above sea level, and of glacial Lake Coeur d'Alene 2,691 feet (820 meters); channel heads along the northern edge of the plateau range from 2,400 to 2,500 feet (732 to 762 meters), and highest records of glacial water there are 2,550 feet (777 meters). Failure of the ice dam for glacial Lake Missoula at Lake Pend Oreille would allow about four-fifths of the total impounded waters to escape southwestward, if no glacial ice obstructed the valley at Rathdrum Prairie. If an ice dam then existed in the Columbia west of Grand Coulee, this water must have escaped across the plateau along the scabland routes. (Modified from Lobeck's "Physiographic diagram of the United States," 1922.)



GEOLOGIC MAP OF GRAND COULEE, WASHINGTON



GEOLOGIC MAP OF GRAND COULEE, WASHINGTON

with ragged buttes and cliffs. In places the buttes outline a maze of channels among them. This feature is best developed along the west side of the coulee between Mesa and Connell.

North of Connell the railroad climbs out of the coulee and traverses Paradise Flats for 15 or 20 miles (24 to 32 kilometers). The flats are probably an aggradational plain determined by the Ringold formation, a late Pliocene or early Pleistocene deposit of the Columbia River. To the east is higher rolling country, the Miocene basalt here carrying a heavy loessial mantle. Scabland lies to the west, too far from the observer to be recognized.

At 25 miles (40 kilometers) from Connell this branch of the Northern Pacific Railway crosses, by trestle, the main line of the Chicago, Milwaukee, St. Paul & Pacific Railroad. This point is on the eastern margin of a tract of wild scabland (Drumheller Channels), but only one minor spillway can be seen. A low east-west ledge across the drainageway extends for 1½ miles (2.4 kilometers) west of the railroad. It is interpreted as a wide, low cataract. The hill 2 miles (3.2 kilometers) west of the track was an island in the glacial flood, but most of the southward discharge along this spillway flowed past the far side of it.

From West Warden to Adrian, a distance of 40 miles (64 kilometers), the route is close to the upper limit of glacial water in a wide, shallow structural basin (the Quincy Basin). There are no marked features of scabland or of loess-covered country here and no contact indicated by scarping of the higher older surface to the east. Near Gloyd can be glimpsed low, bare buttes projecting through a thin gravel deposit. Marked scabland and broad flattish mounds of gravel appear at Adrian (trestle crossing of Great Northern Railway), where a large glacial river entered the Quincy Basin from the east.

From Adrian to Coulee City the railroad traverses typical scabland. About 5 miles (8 kilometers) beyond Adrian the route runs along the rugged eastern wall of Dry Coulee, an abandoned Pleistocene watercourse which was supplied by diverging overflow from Grand Coulee farther west. At 12 miles (19 kilometers) from Adrian the railroad passes the head of Spring Coulee, to the east, and a glimpse of this canyon channel, also a distributary route from Grand Coulee, may be had. Within about 5 miles (8 kilometers) from Coulee City the railroad follows a canyon eroded by cataract recession and passes the abandoned cataract itself. Coulee City lies on the main channel floor between the mouth of upper Grand Coulee and the head of lower Grand Coulee. The first part of the excursion will deal with the lower coulee, south of the town. In the second

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part the environs of Coulee City and the upper coulee will be studied and a traverse made to Spokane (spo-can′), across the upstream portions of the scabland system. The magnetic declination at Grand Coulee is 23° E.

GREAT CATARACT GROUP AT HEAD OF LOWER GRAND COULEE

I–A.[1] Castle Lake Falls, 1 mile (1.6 kilometers) southwest of Coulee City (altitude 1,584 feet, or 483 meters) surface of lake, 1,327 feet (404 meters). Height of cliff at northwest corner of lake, 273 feet (83 meters). Depth of lake reported to be 30 to 40 feet (9 to 12 meters). Deep Lake, seen farther south, is 96 feet (29 meters) lower than Castle Lake, and its depth is unknown. The summit of the butte in the middle of the Castle Lake alcove is 73 feet (22 meters) above the lake surface.

If this is an extinct waterfall, (1) the lake occupies a plunge pool, (2) the cliffed alcove was caused by cataract recession, (3) the scabland crossed in walking from Coulee City is a stream-bottom surface, and (4) water discharging over the fall had to cross an altitude of 1,560 feet (475 meters) about half a mile (0.8 kilometer) north of the brink.

A walk of about 3½ miles (5.6 kilometers) will be necessary to cross the coulee floor to Dry Falls (station I–C).

I–B. Fall and recessional gorge, half a mile (0.8 km.) west of Castle Lake. The cliff is 140 feet (42.7 meters) high at the head, and water discharging over it had to cross a stream floor 1,600 to 1,620 feet (488 to 494 meters) above sea level just to the north. Less than half a mile (0.8 kilometer) farther south the floor of the alcove descends 120 feet (36.6 meters) over another cliff to the bottom of another crescentic alcove. These cataracts could not begin development until the major fall had receded at least half the length of Deep Lake. At that time, therefore, the 1,620-foot (494-meter) floor above the cataract group was under the glacial stream.

From this point, or near it, a glimpse can be had of the potholes in the ledge along the south side of Deep Lake. On the sky line to the southeast is the scabland summit of High Hill anticline.

I–C. Dry Falls (pls. 3, 4), in a double alcove with a long, narrow butte separating them. The total width is 5,800 feet (1,768 meters), the maximum height of the cliff 400 feet (122 meters), the least height 300 feet (91 meters). Fall Lake, in the western alcove, is 80 feet (24 meters) deep, and its surface is 1,202 feet (366 meters) above sea level, or 380 feet (116 meters) below the Vista House. If the coulee floor above these alcoves

[1] Numbers correspond to those shown on placards at stations on the route of the International Geological Congress excursion.

is a stream bed, water had to cross an altitude of 1,530 feet (466 meters) about 1 mile (1.6 kilometers) north of the eastern alcove and an altitude of 1,540 feet (469 meters) less than a quarter of a mile (0.4 kilometer) north of the western alcove, whose brink is lowest of all. The lip of this western alcove ranges through 60 to 80 feet (18 to 24 meters) of altitude. The lowest notch in the lip is not supplied by any local deep channel above.

If this is an abandoned cataract, the entire brink of the western alcove was in action almost to its final stage. If the entire group of alcoves is a waterfall group, no cataract member was ever abandoned because a competing member by greater recession cut off its supply.

LOWER GRAND COULEE

II–A. Characteristic channel floor along the west side of the Dry Falls alcove. The total descent from this floor to Park Lake is about 450 feet (137 meters).

II–B. View of lower coulee walls, looking south; Park Lake occupies coulee floor. Western wall 700 to 1,000 feet (213 to 305 meters) high; eastern wall 400 to 500 feet (122 to 153 meters) high. Scabland on top of the eastern wall; normal gullied slopes above the western wall. The tilted beds of the Coulee monocline have been removed in making this canyon. Stratigraphically the base of the eastern cliffs belongs above the summit of the western cliffs.

II–C. Gravel and cobble deposit at left, traversed by the highway serpentine curves. Foreset beds, dipping eastward (up the coulee). Mounded gravel deposit at right, extending thence down to Park Lake, 160 feet (49 meters) lower.

II–D. Tilted basalt flows of Coulee monocline in wall above the gravel deposit at left. Maximum dip is 60°.

II–E. Mound of gravel along east side of Park Lake, traversed by highway. Maximum altitude reported to be 263 feet (80 meters) above lake surface. Interpreted as a river bar. The lake is 150 feet (46 meters) deep.

II–F. At right, hogback islands in Park Lake, remnants of the monoclinal structure.

II–G. At right, remnant of dipping flows of Coulee monocline in western wall at lower end of Park Lake.

II–H. Short detour from highway to McCann bathing beach, at north end of Blue Lake, to see Jasper distributary canyon, leading eastward out of the lower coulee. The mounded gravel deposit (river bar?) seen in this distributary canyon rises 150 feet (46 meters) above the lake, which is here 40 feet (12 meters) deep.

II–I. Between Blue Lake and Lake Lenore can be seen the hanging entrance to Lenore Canyon, another distributary canyon leading eastward out of Grand Coulee. The gravel deposit reaches a maximum of 330 feet (100 meters) above the lakes. Closed depressions among the gravel mounds are as much as 135 feet (41 meters) deep in Lenore Canyon.

II–J. Hogback islands in Lake Lenore. The road traverses one of these islands.

II–K. At left, toe of the monocline, dipping into the cliff along the east side of Lake Lenore.

II–L. At right, scabland ledges on west side of lake, below the talus and west of the monocline.

II–M. At right, hanging valleys notching the summit of the western wall.

II–N. South end of scabland ridge separating two parallel channels. The channel to the west, containing Lake Lenore, is limited to the monoclinal belt. The depth of the lake is unknown, but its surface is here about 200 feet (61 meters) below the floor of the eastern channel, which lies in a shallow syncline. The two channels lie side by side for about 5 miles (8 kilometers), and the floor of the eastern one rises northward to 400 or 500 feet (122 to 153 meters) above the lake. The prominent bladelike butte on the dividing ridge is about 200 feet (61 meters) above the eastern channel floor.

An abandoned cataract at the south end of the synclinal channel is about 100 feet (30 meters) high. A rock basin in the channel floor, 1,000 feet (305 meters) upstream from this cataract, is 100 feet (30 meters) deep.

A mounded gravel deposit (bar?) lies on the channel floor at the east end of the cataract ledge and continues downstream past the plunge-pool basin. This is interpreted to mean that the ledge was completely submerged beneath the glacial stream.

On the higher slopes east of the synclinal channel (High Hill anticline) are preglacial tributary valleys, hanging only slightly above the channel floor. These contrast with the hanging preglacial valleys high on the western wall.

The synclinal channel is believed to occupy here the main preglacial drainageway in the structural valley east of the monocline. Before the arrival of glacial water the monoclinal slope had no canyon along it, the hanging valleys above the western cliff then being continuous across the present lake canyon to the synclinal valley.

South from this station Grand Coulee swings eastward out of the monocline and crosses two low anticlines. The cliffs west of Soap Lake belong to the High Hill anticline; those east of the lake to the Pinto Ridge anticline.

COULEE MONOCLINE AND CLIFF SUMMIT WEST OF LAKE LENORE

III–A. Gravel bar (?) elongated along the slope and originally blocking the local run-off. An aggraded flat lies in the small basin on the uphill side, and a gully through the bar now drains the depression.

III–B. Stream gravel west of Soap Lake, up to 1,400 feet (427 meters) above sea level, or 313 feet (95 meters) above the the lake. None higher on this slope. The valley here is structural in origin, not erosional.

III–C. Highest erratic boulders, up to 1,487 feet (453 meters) above sea level.

III–D. At right, saddle at 1,750 feet (533 meters), unscarred by glacial water. The hill between the saddle and Soap Lake is the High Hill anticline.

III–E. Viewpoint near cliff brink. The hanging valleys of the west wall, seen close at hand, are thought to be the heads of tributaries once leading across the site of the monoclinal canyon to the eastern or synclinal channel. (See pls. 5, 6.) Fans lie at the foot of the monocline where not affected by the glacial flood and may well have existed at the bottom of this slope. Higher places on the mid-channel ridge may be relics of divide spurs between the vanished lower reaches of these hanging valleys.

The course of the High Hill anticline across the coulee floor is marked by the scabland northwest of Soap Lake.

QUINCY BASIN NEAR EPHRATA

IV–A. Northward slope of the débris fill at the mouth of Grand Coulee, in Quincy Basin. From Soap Lake to Ephrata (altitude 1,277 feet, or 389 meters) the surface rises 190 feet (58 meters) in the downstream direction. Near Ephrata it has a channel-like character, but though the "channel" is lower and wider to the north, the water flowed to the south, out of Grand Coulee.

IV–B. Gravel of Quincy Basin, 1 mile (1.6 kilometers) south of Ephrata. The deposit here is 60 feet (18 meters) above the "channel" floor and 250 feet (76 meters) above Soap Lake, yet it is downstream from the lake basin. The only evidence of dissection is the "channel." The gravel, shown in cuts, is weathered but slightly and to shallow depths. It consists almost wholly of basalt from the erosion of Grand Coulee.

Across the channel to the northwest is a piedmont waste slope at the foot of the Coulee monocline. Its débris is little rolled,

considerably weathered, and poorly sorted and stratified and consists entirely of basalt. Such a waste fan may have lain along the west side of the synclinal channel, near Lake Lenore, before the monoclinal channel was cut.

The fan deposit has been truncated by the glacial stream that made the Ephrata channel and deposited the gravel at station IV–B. Both channel and gravel deposit are considered to be bar features, the glacial river flowing over the whole surface.

SCABLAND AND BARS (?) OF CRAB CREEK

Traverse eastward across the gravel deposit at the mouth of Grand Coulee and up a scabland channel that enters Quincy Basin east of Grand Coulee. None of the gravel shows terrace forms, gullies, or other evidence of dissection. Its present topography is essentially its original topography. Scabland is absent as far as Adrian (the eastern edge of the basin). Altitudes along the route:

Adrian (overhead railroad trestle, 12 miles (19 kilometers) from Ephrata), 1,234 feet (376 meters); Stratford (on the right, 8 miles (13 kilometers) east of Adrian), 1,279 feet (390 meters); Wilson Creek, 1,327 feet (404 meters).

V–A. The scabland forms, interpreted as results of glacial stream erosion, have been developed here on the slopes of a preglacial valley essentially as deep before the flooding as now. The upper limits of scabland here are 260 feet (79 meters) above the town of Adrian. Thus the valley became a channel. All erosional and depositional forms within the immediate view are either wholly subfluvial in origin or are channel modifications of preexisting valley features. The depth of the glacial stream, by this view, was as great as the vertical range of scabland (260 feet, or 79 meters).

The viewpoint is on a scabland ledge on the south side of Crab Creek. To the west (down the valley) is an elongated mounded gravel deposit on the valley floor in the lee of this ledge. The main valley is north of it, and a partly inclosed depression lies on the south, between the mound and the valley wall. The mound is interpreted as an accumulation in situ of the traction load swept along by the glacial stream—a river bar. It lies in a protected place, its form and orientation are exactly as required by this interpretation, and it can not be satisfactorily explained as an erosional remnant of a once continuous gravel deposit.

Beyond this bar may be seen a row of scabland buttes projecting southward into the valley from the cliffs on the north side. They are interpreted as remnants of a preglacial slip-off

slope, trenched and gashed by the great stream that used this valley as a channel. The return trip to Coulee City will allow opportunity to see them more closely, to note the deep notches (one of which is used by the Great Northern Railway), to observe the long bars that depend westward in their lee, and to recognize more clearly that the preglacial valley here had a definite southward curve around these bars.

V–B. The road up the south slope of Pinto Ridge climbs above the limit of glacial water in the Crab Creek Valley. On the left is another side-hill bar of basaltic débris with a fosse or depression back of it. A short distance above this bar the hill is completely mantled by loessial soil and has no scabland features.

SCABLAND AND DISTRIBUTARY CANYONS EAST OF LOWER GRAND COULEE

VI. An excellent view can be obtained from this northern part of Pinto Ridge summit. The course of lower Grand Coulee is easily traced by the western cliff with its hanging valleys. High Hill lies nearly due west between the coulee and the observer. North of it is Lenore Canyon, a distributary course across the High Hill anticline cut nearly as deep as lower Grand Coulee. The lowland in the foreground is a structural valley, the Bacon syncline. The glacial flood entered it over the summit of the High Hill anticline, denuding about 12 miles (19 kilometers) of its crest line. Six canyons trenched by this discharge from the north can be seen, of which Grand Coulee and Lenore Canyon are the deepest. Two others, deeply cut in the southern flank of the anticline, had driven their cataract heads well north of the axis of the fold before being abandoned.

The southern slope of the High Hill anticline carries several large mounds or shoulders of gravel projecting toward the Bacon syncline on the ridges between the canyons. Like similar features already examined, they are considered to be bars of the great glacial river.

The water that was poured over into the Bacon syncline escaped by two routes to Quincy Basin, one on each side of Pinto Ridge. Both exhibit marked scabland features several hundred feet up on their slopes. The uppermost record of scabland water on the north slope of Pinto Ridge is nearly 1,800 feet (549 meters) above sea level and not far below the viewpoint.

HARTLINE BASIN SCABLAND AND GRAVEL

VII–A. Scarp 1 mile (1.6 kilometers) east of Coulee City, rising from the channel bottom to a broad gravel-covered flat. Considered to be largely a subfluvial slope, determined by distributary discharge eastward into the Hartline structural basin.

VII–B. Gravel-covered flat. Gravel almost wholly basaltic, fresh almost to the surface. Loess is encountered in wells beneath 25 feet (8 meters) of this gravel 1 mile (1.6 kilometers) east of the scarp. The gravel plain locally slopes up southward toward the scabland summit of the High Hill anticline.

VII–C. Isolated scabland in the basin. The crest of the lowering anticline toward the east, eroded by the glacial water sweeping southeastward out of Grand Coulee and over into the Bacon synclinal valley. Associated bar forms indicate direction of flow.

VII–D. A bar front, facing east, all along the eastern margin of the gravel. Foreset beds dipping eastward out of Grand Coulee.

VII–E. Monoclinal slope with normal erosional forms above the level of glacial water. Section of gravel flat in northern part.

VII–F. Pit in brink of scarp overlooking Grand Coulee channel floor. Foreset beds dipping northeast in lee of salient at mouth of upper coulee.

SCABLAND AND BARS OF HIGH HILL ANTICLINE

The summit of the anticline reaches an altitude of 1,800 feet (549 meters) in several places. This is 200 feet (61 meters) higher than Coulee City. The anastomosing character of scabland channels over the entire summit, the uphill downstream gradients, the rock basins, and the youthfulness of the surface are all to be noted. This summit topography and soil contrast with those on Pinto Ridge.

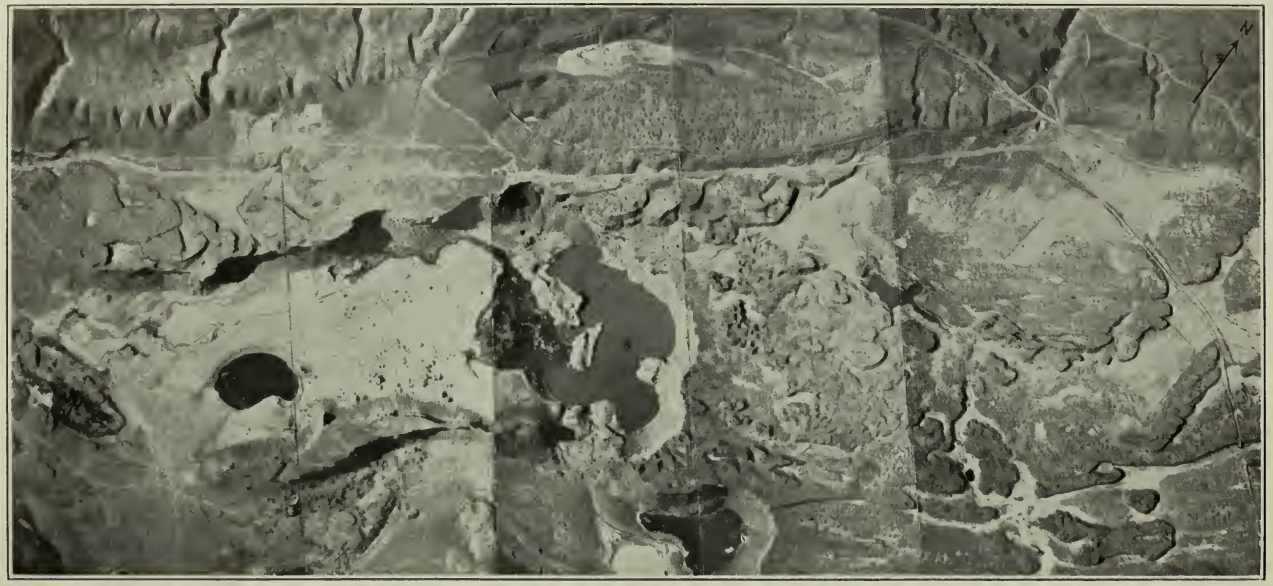
VIII–A. Trail Lake at the left, in the head of one of the canyons down the south slope. Cataract cliffs of this canyon head, 100 feet (30 meters) high, are 1 mile (1.6 kilometers) north of the anticlinal axis. No such canyons occur down the north slope. Anticlinal structure is exhibited in canyon walls between stations A and B.

VIII–B. Great gravel mound projecting southward from the anticline into the synclinal valley, with its summit nearly as high as the anticlinal crest. Its location between canyons and its constructional form are noteworthy. The bar is about 200 feet (61 meters) high at the south end.

VIII–C. Outcrop of loess about 50 feet (15 meters) thick beneath gravel at south end of the bar.

On the return to Coulee City other bars similar in character and location, but smaller, can be seen. There are no such bars on the north side of the anticline or the south side of the syncline. A small cataract is passed along the highway just before reaching the summit of the anticline.

PLATES 3–9



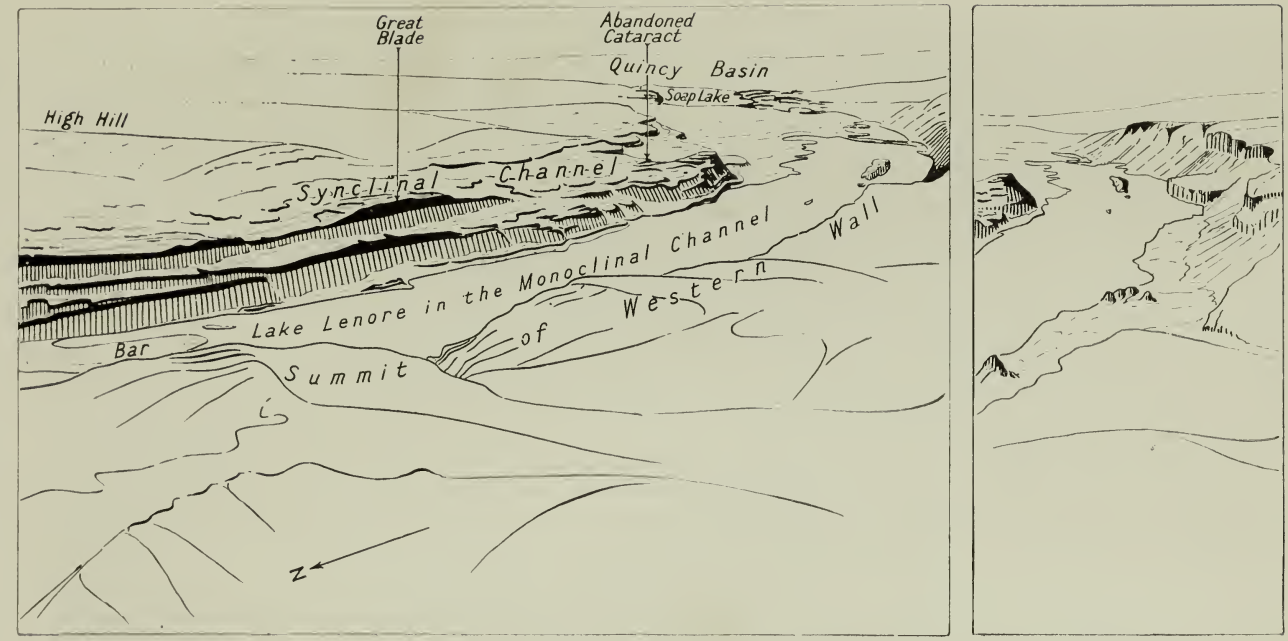
DRY FALLS PORTION OF THE GREAT CATARACT GROUP, LOWER GRAND COULEE

Shadows occur only on eastward-facing cliffs. Other cliffs are identifiable by their talus zones. Fall Lake is bordered on the northeast by the cataract cliff, 400 feet (122 meters) high except where a deeper channel enters it at the north. The western part of the lake basin has been filled in by a swamp. The smaller eastern alcove, close to the margin of the picture, contains both a lake and a swamp. Above the cataract brink is butte and basin scabland channel bottom with a maximum relief of 100 feet (30 meters) showing. (Mosaic of vertical aerial photographs, Grand Coulee series, Nos. 26–30, U. S. Geological Survey.)

KEY TO PLATE 3

SYNCLINAL AND MONOCLINAL CHANNELS, LOWER GRAND COULEE

The pictures are from two slightly different viewpoints, juxtaposed to make a composite. The observer is looking southeast from an altitude of about 1,500 feet (457 meters) above the lake. The high places on the median ridge may be remnants of preglacial divides between gulches that crossed the site of the ridge at the sags in its crest. (Oblique aerial photographs by Libby & Son.)

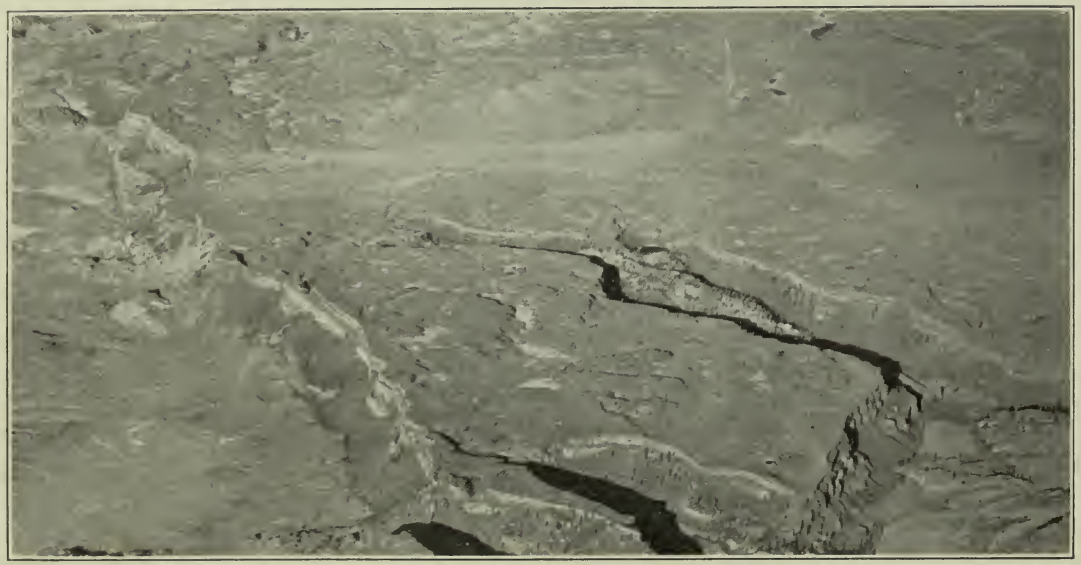


KEY TO PLATE 5

LATERAL CATARACT RECESS AND BAR, UPPER GRAND COULEE

The ephemeral lake on the coulee floor is 9 miles (14 kilometers) north of Coulee City. A delta fan has been built into it by a gully from the east, the gully eroded in a large bar in the lowest part of the niche. Elsewhere the floor is the silt plain. (Mosaic of vertical aerial photographs, Grand Coulee series, Nos. 139–143, U. S. Geological Survey.)

KEY TO PLATE 7



HEADS OF NORTHRUP CANYON GROUP, UPPER GRAND COULEE, LOOKING NORTHEAST

The dissected silt deposit on the floor of the coulee shows on the left. The summit scabland is about 900 feet (274 meters) higher. A median granite ridge shows in the most distant canyon. Note the canyon head that notches the coulee wall, lower edge of the photograph. (Photograph by Brubaker.)

UPPER GRAND COULEE

IX–A. At right, crossing of coulee and monocline, 4 miles (6.4 kilometers) north of Coulee City. This is the northern limit of the scabland on the coulee floor. Wells in the upper coulee, though penetrating 109 to 200 feet (30 to 61 meters), uniformly fail to find rock.

IX–B. Hanging "valley" and mounded gravel deposit 9 miles (14.5 kilometers) north of Coulee City. Plate 7 shows the character of this rugged cliffed niche in the coulee wall, which contrasts with the hanging valleys west of Lake Lenore and on the opposite side of the coulee here. The whole summit of the eastern wall of the upper coulee is scabland, much like that on the summit of the High Hill anticline. Though 800 to 900 feet (244 to 274 meters) above the coulee floor, it is a glacial stream bottom. The niche is identical with the smaller alcoves of the great cataract group. Its interpretation as a lateral cataract spilling over the Grand Coulee wall requires that the upper coulee itself be the gorge of a recessional cataract and permits no preglacial valley across the divide.

The top of the bar in the lowest part of the niche stands 163 feet (50 meters) above the adjacent playa basin and 85 feet (26 meters) above a fosse between it and the rock walls to the east. Foreset beds in the western slope dip down the coulee; those in the eastern slope dip up the coulee. The mound is interpreted as a bar formed in an eddy after the lateral cataract had been abandoned. A climb to the summit will afford a view of the constructional form.

IX–C. Glacial silt overlying boulder deposit 40 feet (12 meters) above the near-by channel floor. All wells that penetrate the silt find sand, gravel, or boulders beneath.

IX–D. At right, Martin Falls, a storm-water cataract out of another lateral waterfall over the eastern coulee wall. The upper coulee widens in this latitude to a maximum of 5 miles (8 kilometers), four times its width for the first 11 miles (17.7 kilometers) traversed.

IX–E. At left, view of east side of Steamboat Rock. The ledge about halfway up is the floor of a scabland channel. Another channel crosses the top, and the whole summit is scabland, similar to and at the same altitude as that on top of the eastern cliff. The coulee is twice as wide on the west side of Steamboat Rock as on the east. The eminence is interpreted as an island in a double cataract which reunited to the north, similar to Goat Island in Niagara Falls.

IX–F. At right, a view of the mouth of Northrup Canyon, a very peculiar "tributary" which will be seen from above later in the trip.

IX–G. At right, another view of a part of Northrup Canyon, where one of the branches of this "tributary" heads back in Grand Coulee. Buried granite hills exhumed by erosion of the glacial torrent are also seen.

IX–H. Lovers Lane, a narrow gorge cut through a granite hill. There are several such gashes through granite knobs in this part of the coulee. They are considered to be channels of the glacial river. The map shows the row of granite hills interrupting the coulee at this place.

IX–I. Narrowing of coulee at head, its width here decreasing to that of the first 11 miles (17.7 kilometers) traversed. The widened portion, marked by Steamboat Rock and the large granite hills, is not explained by their presence, as the map will show. The favored interpretation is that the widening was due to a greatly increased discharge of the glacial river and that this diminished to its former volume before the cataract reached the Columbia Valley.

IX–J. View of coulee head and Columbia Valley. An exposed rock floor exists at each end of the upper coulee, but none throughout its length. Both exposed floors have the same altitude, about 1,500 feet (457 meters.) There is no continuous gradient along this 25-mile (40-kilometer) canyon, nor is the depth to rock known. The deepest well on the coulee floor, northwest of Steamboat Rock, finds no rock at 1,313 feet (400 meters) above sea level, 200 feet (61 meters) below the lowest scabland at Coulee City. Upper Grand Coulee thus contains a greatly elongated rock basin, largely but not entirely filled with sand, gravel, and boulders, covered with glacial silt.

The silt terraces of the coulee are continuous with those in the Columbia Valley. No similar silt is known in the lower coulee or in the Columbia Valley west of the head of Grand Coulee. Apparently a lake existed east of an ice or drift barrier in the Columbia Valley and extended down the coulee nearly to the great cataract group.

The floor at the head of Grand Coulee hangs about 600 feet (183 meters) above the Columbia. The total depth of the Columbia Valley here is about 1,500 feet (457 meters). Preglacial ravines (the road is in one) and gentler slopes of the Columbia Valley indicate that the coulee is a much younger feature.

IX–K. Scabland above the eastern wall of Grand Coulee, 800 to 900 feet (244 to 274 meters) above the coulee floor, 4 miles (6.4 kilometers) wide. East of it is the loess-covered plateau,

without a sign of glacial ice or water. The upper limit of glacial record here is about 2,400 feet (732 meters) above sea level.

IX–L. Viewpoint just south of Northrup Canyon. The airplane photograph in Plate 9 shows this "tributary" canyon to have three branches, each of which leads (upstream) back toward the coulee wall and one of which actually notches the wall, almost making another Steamboat Rock. The water that eroded these canyon heads came out of Grand Coulee; hence they are distributary, rather than tributary. The close resemblance of the middle branch to the alcoves of the great cataract group indicates similarity of origin. With all other items in harmony, Northrup Canyon becomes a cataract group more striking than the Castle Lake Falls and its closely associated alcoves.

The map shows three other large cataract alcoves interrupting the western wall of the coulee in this widened place. It appears that at the time the glacial river was so greatly augmented that the main cataract, although 4 to 5 miles (6.4 to 8 kilometers) wide, was not disposing of all the water, the glacial river across the scabland above the falls (the summit scabland) was wide enough to demand more and larger laterals than at any other time in the upper coulee's history. The narrowing at the head seems to record cessation of this flood and return of a normal glacial river before the great fall had receded through to the Columbia.

It is presumed that the monoclinal channel of the lower coulee, the great bars of Quincy Basin (seen at Ephrata), and the denudation of the High Hill anticline are products of the same flood that made the widened upper coulee and its huge lateral alcoves.

ROUTE TO SPOKANE OVER SUNSET HIGHWAY

The following features should be noted on the route to Spokane:

1. Anastomosis of different scabland routes.
2. Four major scabland routes, of which Grand Coulee is one.
3. Channel modification of normal preglacial valleys.
4. Isolated loessial hills, especially southeast of Creston and west of Davenport.
5. Complete removal of loess over large areas in vicinity of Telford.
6. Scabland across preglacial divides—between Wilbur and Creston, about Telford, and just east of Reardan.
7. Glaciated region between Deep Creek and Spokane.
8. Upper limits of scabland features.

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